JPL Publication 19-3

2018 NISAR Applications Workshop: Wetlands

Workshop Report

Natasha Stavros, Jet Propulsion Laboratory, California Institute of Technology

Bruce Chapman, Jet Propulsion Laboratory, California Institute of Technology

Marc Simard, Jet Propulsion Laboratory, California Institute of Technology

Batu Osmanoglu, NASA Goddard Space Flight Center

Cathleen Jones, Jet Propulsion Laboratory, California Institute of Technology

Raha Hakimdavar (US Forest Service)

John W. Jones (Hydrologic Remote Sensing Branch, US Geological Survey)

Gerald Bawden, NASA Headquarters

National Aeronautics and
Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

June 2019

This publication was prepared by, and part of this work was carried out at, the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.

Report Writing Committee

- Natasha Stavros (Jet Propulsion Laboratory, California Institute of Technology)
- Bruce Chapman (Jet Propulsion Laboratory, California Institute of Technology)
- Marc Simard (Jet Propulsion Laboratory, California Institute of Technology)
- Batu Osmanoglu (NASA Goddard Space Flight Center)
- Cathleen Jones (Jet Propulsion Laboratory, California Institute of Technology)
- Raha Hakimdavar (US Forest Service)
- John W. Jones (Hydrologic Remote Sensing Branch, US Geological Survey)
- Gerald Bawden, NASA Headquarters

Workshop Organizing Committee

- Natasha Stavros (Jet Propulsion Laboratory, California Institute of Technology)
- Marc Simard (Jet Propulsion Laboratory, California Institute of Technology)
- Bruce Chapman (Jet Propulsion Laboratory, California Institute of Technology)
- Megan Lang (Fish and Wildlife Service)
  Greg Snyder (US Geological Survey)
- Cathleen Jones (Jet Propulsion Laboratory, California Institute of Technology)
- Susan Owen (Jet Propulsion Laboratory, California Institute of Technology)

Table of Contents

1 Executive Summary

Wetland ecosystems are a critical part of our natural environment, providing socioeconomic benefits to human communities and habitats to a rich diversity of plant and animal life. Socioeconomic benefits include improved water quality, flood control, foods, shoreline stabilization, groundwater recharge, and recreational opportunities. Wetlands also have a major role as carbon sinks and sources through processes that are influenced by the duration and timing of soil saturation and inundation. Thus, carbon and water cycle models must take into account wetland extent and seasonal patterns of wetland inundation. The joint NASA, US Geological Survey (USGS) and Fish and Wildlife Service (FWS) workshop focused on advancing wetland applications of the spaceborne NASA-ISRO Synthetic Aperture Radar (SAR) mission (NISAR), a jointly developed satellite between NASA and the Indian Space Research Organisation (ISRO) expected for launch early 2022. Participants from 15 national and international organizations --including US Federal Agencies, nonprofits, academics, and the private sector-- had been identified as key-players in facilitating integration of Earth Observations into decision support workflows. Discussions were held over two and a half days to convey the knowledge and measurement needs of the wetlands community and discuss the delivery of relevant geospatial products that could be derived from NISAR data. While the community typically characterizes wetlands by their hydrological process, vegetation and soil types, a central defining characteristic is that a wetland is a land area inundated or saturated in the rootzone for at least 2 weeks of the average vegetation growing season. Case studies were presented to demonstrate the current state of practice in the use of SAR remote sensing for applications of direct importance for wetlands community. A questionnaire provided by the NASA team was used to identify science data requirements, enabling the NASA team to assess NISAR ability in responding to these requirements. These discussions enabled specifications (e.g., resolution, projection, latency, etc.) of wetland products to increase utility of NISAR data and design demonstration studies.

The general findings of this workshop were that:

- NISAR observations will be particularly useful to the wetland community if Level-3 products are generated for change through time of: 1) inundation/surface water extent, 2) soil moisture, 3) wetland extent in vegetated areas, and 4) surface water stage (i.e. level) change in time.
- NISAR products should be GIS-ready and distributed with scripts enabling users to generate above-mentioned level-3 time series with user-specific spatial and temporal resolution.
- There is a need for pre-launch simulation of NISAR time-series data for Level-3 products to assess the capability of NISAR to sample highly variable temporal dynamics of wetlands.
- There is a need for a dedicated NISAR Wetlands Applications Working Group (as per the specifications in the NISAR Utilization Plan) to provide: 1) provide input on relevant calibration and validation sites for identified products of interest, 2) develop strategies for gaining traction within the respective agencies and organizations for use of NISAR data, and 3) determine how to go from unprocessed NISAR data to the wetland products (Section 6) needed by decision support systems.

2 Overview

Monitoring and measurement from earth observing satellites have been a means for understanding the natural resources of our planet for over 40 years. However, in the last 10 years, with the development of innovative signal processing techniques, the ability to measure changes in soil moisture, inundation extent and 3-dimensional structure of wetland vegetation has advanced. NASA's upcoming NISAR mission will be unique in providing comprehensive, frequent and consistent imaging of all lands globally (except for the Sahara), twice every twelve days, with open access to the data. The aim of the NISAR Wetlands Applications Workshop was to determine how to leverage the NISAR mission for monitoring wetlands globally. The workshop was held on October 23-25, 2018 at the Fish and Wildlife Service (FWS)/US Geological Survey (USGS) Patuxent Wildlife Refuge in Laurel, Maryland with representatives from 15 national and international organizations (e.g., non-profits, private, and government agencies).

2.1 Workshop Objectives

The NISAR Wetlands Applications Workshop focused on four overarching objectives derived from input provided in the omnibus 2015 NISAR Applications Workshop. In the 2015 workshop, NISAR received a recommendation to focus the workshops around thematic communities with varying capabilities for handling Synthetic Aperture Radar (SAR) data and with different measurement requirements. To meet these recommendations, NISAR worked with the FWS and USGS to tailor the objectives to first identify high impact applications for integrating NISAR into Wetlands Applications. High impact was defined to be a function of relevance of the application to many diverse organizations and agencies working with wetlands, feasibility of the NISAR observation and latency deliverables to meet application requirements, feasibility of the user community to ingest and use the data, and maturity of algorithms for producing required information and value-added products (Data Level 3+) for operational deployment globally. The second objective was to develop a roadmap for realizing integration of SAR into wetland management decision support systems for the identified high impact applications, recognizing that NISAR can complement the long-standing established community of practice and decades of developed infrastructure already used for management wetlands and decision making. The third objective was to identify early engagers (analogous to "early adopters"; see the NISAR Utilization Plan) to help develop value-added information products (Data Level 3+), test application of the data in the decision-making context, and distribute to the broader wetland management community. The fourth and final objective was to identify partners for calibration and validation of NISAR Level 3+ information products, particularly those being developed by the project and distributed over calibration/validation sites.

2.2 Workshop Format

The two-and-a-half-day workshop was designed to meet the objectives with the first day focused on identifying high impact applications and the second day focused on developing a road map and identifying early engagers. The last day was dedicated to follow-up discussions on the NISAR calibration and validation for the inundation extent algorithm and a Wetlands Applications Working Group.

2.2.1 Workshop – Day 1

In the morning of the first day, we had morning welcomes by NASA, FWS, and USGS that introduced the respective agencies' missions, and organizations. After a break, we reconvened for an overview of the NISAR mission and descriptions of the algorithms being developed for Inundation Extent mapping as well as an overview of the utility of SAR observations for wetlands. The rest of the morning and into the afternoon, the wetland community representatives presented their agency/organization mission, site description, information needs (measurements, spatial and temporal resolutions and distribution latency), current remote sensing capabilities and biggest challenges within their agency/organization. Specifically, participants answered the following questions:

1. What is the mission of your organization?
2. Describe your wetlands sites. Are the areas vegetated or open water? If vegetation, how much biomass? What type of vegetation and what is the structure (emergent/herbaceous, shrub/scrub, trees)? What are the temporal dynamics of the wetlands (hydroperiod or water regime, and vegetation phenology)? What are the spatial extents and target mappings unit of the wetlands you observe? What is the shape of the wetlands (e.g., linear, channels, etc.)? Is there infrastructure present?
3. Does your organization have a requirement of routine monitoring? If yes, what particular attributes? Examples: inundation extent, inundation depth, carbon stocks, tree height, vegetation cover, species composition, land loss from sea level rise, etc. and what are the associated temporal resolution and latency (from observation to in hand, or from observation to higher level information product) for reporting/monitoring?
4. Does your organization have a response/recovery mission or mandate in the event of a disaster (hurricanes, tsunamis, flooding, drought, etc.)? If so what primary information products do you rely on? What are your latency requirements (from observation to in hand, or from observation to higher level information product)?
5. How are remote sensing data (optical, lidar, stereo photogrammetry, radar) used in your decision support systems for wetlands? If so, describe the type of data and applications. What is your organization's capability for integrating in remote sensing data (i.e., in-house product generation or GIS-ready)? For integrating SAR?
6. What are the landscape-scale observations that could significantly address the most challenging problems of your organization?
7. How would a twice-every-12 day-repeat, cloud-free, hectare-scale SAR monitoring capability impact your workflow/decision support system?

After a mid-afternoon break, everyone reconvened to clarify similarities and differences across agencies and organizations in an open discussion. The NISAR Science Team responded with technical NISAR capabilities and expected Level-3 data products and latency, and noted the need for capacity building. The day concluded with a cautionary word from NASA Headquarters on funding limitations, and a request for collaboration to fulfill additional needs.

2.2.2 Workshop – Day 2

The second day focused on developing a roadmap for the integration of NISAR data into the wetland community decision support infrastructure, and identifying the potential for early engagers through an ad hoc working group. In the morning, there were several organizational presentations highlighting feasibility studies that used SAR data to produce value-added information products and integrate them into the decision-making context. These presentations addressed the following questions:

- What was the organization/decision making context?
- What was the information gap?
- Why was SAR a good fit?
- What did the algorithm look like? Which band and frequency were used? How well did it perform?
- How was it integrated and tested in the decision-making context?
- What were the challenges or lessons learned about integrating SAR data into a local decision-making context? What worked? What didn't? Why didn't it?
- Is it something that will be sustained or augmented once L-band SAR from NISAR is made globally and publicly available? Can we possibly use this in other places (i.e., how extractable is it)?

The presentations and lunch were followed by an engaged 2-hour discussion on needed products and a roadmap to develop these products. No time was left to discuss needed training. Questions about products were: Which wetlands applications products serve multiple agencies/organizations? What are the specifications (data formats, projections, etc.) for the NISAR products? Questions about the roadmap were: What is the best way to get from NISAR Level 2 radar products to Wetlands science/application-ready products (Level 3+)? Key data producers/providers? Software tools (GEE, ArcGIS plug-ins, etc.)? What is the best way to distribute/disseminate products? Working Group? To end the day, Gerald Bawden, the acting NASA NISAR Program Scientist, concluded with some final thoughts on next steps for the NISAR mission and the community.

2.2.3 Workshop - Day 3

On the final day of the workshop, several members of the community stayed to discuss the needs and available data to support a 12-day repeat airborne campaign in the Southeastern US to support algorithm development and refinement in preparations for NISAR, as well as suggesting activities for a Wetlands Applications Working Group.

3 Mission Overview

3.1 Mission Design

NISAR Characteristic:	Enables:
L-band (23 cm wavelength)	Low temporal decorrelation and foliage penetration
S-band (9 cm wavelength)	Sensitivity to light vegetation
SweepSAR technique with Imaging Swath > 240 km	Global data collection
Polarimetry (Single/Dual/Quad)	Surface characterization and biomass estimation
12-day exact repeat	Rapid Sampling
3 – 10 meters mode-dependent SAR resolution	Small-scale observations
3 yrs (NASA) / 5 yrs (ISRO) science operations	Time-series analysis
Pointing control < 273 arcseconds	Deformation interferometry
Orbit control < 500 meters	Deformation interferometry
> 10% (S) / 50% (L) observation duty cycle	Complete land/ice coverage
Left-only pointing (Left/Right capability)	Uninterrupted time-series Rely on Sentinel-1 for Arctic

Figure 1 – NISAR characteristics and capabilities.

The NASA–ISRO Synthetic Aperture Radar (NISAR) mission is a partnership between NASA and the Indian Space Research Organisation (ISRO), currently scheduled to launch in early 2022 and to have a minimum mission lifetime of three years with consumables up to 15 years. The mission is optimized for studying hazards and global environmental change, specifically in support of ecosystem, cryosphere, and solid earth science. The satellite is designed to provide a detailed view of the Earth to observe and measure some of the planet's most complex processes, including ecosystem disturbances, ice-sheet collapse, and natural hazards.

3.2 Mission Capabilities

NISAR is a very capable radar satellite that will systematically collect L-band data (24 cm wavelength: developed by NASA) over all land and ice-covered regions globally (including sea ice, but currently excluding the Sahara) and S-band data (9 cm: developed by ISRO) across India and selected in selection sites globally with a 12 day repeat orbit and 240 km wide swath (Figure 1). NISAR’s L-band radar instrument will provide all-weather, day/night imaging of nearly the entire land and ice masses of the Earth repeated 4-6 times per month considering both ascending and descending orbits, and the S-band instrument will provide additional coverage of India, parts of the polar regions, and at select calibration/validation sites around the world. Depending upon the operating mode (Table 1), NISAR’s orbiting radar can image at resolutions of 3-50 meters, to identify and track subtle movement of the Earth’s land and its sea ice, and even provide information about what is happening below the surface in areas where subsurface processes result in surface deformation. Regular and consistent repeat imagery can be used to detect small-scale changes before they are visible to the naked eye and to track dynamic changes as conditions evolve.

Table 1 – NISAR L-band and S-band radar modes, science targets, polarizations, pulse bandwidth (BW), pulse width (PW), and image swath width. The ground resolution in the cross-track direction is set by the pulse bandwidth (BW), and is 3/6/12 or 50 m for 80/40/20 or 5 MHz, respectively. The ground resolution in the along-track direction is 8 m for all modes. The instruments can operate in single-polarization (SP) HH or VV (the first letter indicates the transmit polarization and the second indicates the receive polarization, either horizontal or vertical); dual-polarization (DP) HH/HVor VV/VH; co-polarization (QD) HH/VV; quad-polarization (QP) HH/HV/VV/VH, or quasi-quad polarization (QQ) (HH/HV/VV/VH with slightly different frequency H and V transmit). The mode selected depends upon the science target for a given location (see section 3.3). The L-band instrument can also operate in Compact Polarimetry (CP) mode transmitting right circular polarization (R), but there are currently no science plans to systematically utilize this mode.

Science			Performance	
Primary Science Target	Freq Band	Polarization	BW (MHz)	Swath (km)
Background Land	L	DP HH/HV	20 + 5	242
Background Land Soil Moisture	L	QQ	20 + 5	242
Background Land Soil Moisture Hi Pwr	L	QQ	20 + 5	242
Land Ice	L	SP HH	80	121
Land Ice Low Res	L	SP HH	40 + 5	242
Low Data Rate Study Mod SinglePol	L	SP HH	20 + 5	242
Sea Ice Dynamics	L	SP VV	5	242
Open Ocean	L	QD HH/VV	5 + 5	242
India Land Characterization	L	DP VV/VH	20 + 5	242
Urban Areas, Himalayas	L	DP HH/HV	40 + 5	242
Urban Areas, Himalayas SM	L	QQ	40 + 5	242
Urban Areas, Himalayas SM Hi Pwr	L	QQ	40 + 5	242
US Agriculture, India Agriculture	L	QP HH/HV/VH/VV	40 + 5	242
US Agriculture, India Agriculture Low Res	L	QP HH/HV/VH/VV	20 + 5	242
Experimental CP mode	L	CP RH/RV	20 + 20	242
Experimental QQ mode	L	QQ	20 + 20	242
Experimental SP mode	L	SP HH	80	242
ISRO Ice/Sea-Ice	L	DP VV/VH	5	242
ISRO Ice/Sea-Ice - alternate	L	QD HH/VV	5	242
Solid Earth/Ice/Veg/Coast/Bathym	S	Quasi-Quad	37.5	244
Ecosystem/Coastal Ocean/Cryosphere	S	DP HH/HV	10	244
Agriculture/Sea-Ice	S	CP RH/RV	25	244
Glacial Ice-High Res	S	CP RH/RV	37.5	244
New Mode	S	DP HH/HV	37.5	244
Deformation	S	SP HH (or SP VV)	25	244
Deformation-Max Res	S	SP HH (or SP VV)	75	244

3.3 Current Mission Observation Plan

The current NISAR observation plan is to collect L-band SAR HH/HV observations with a 12m x 8m spatial resolution and a 12-day repeat interval across most of the land area outside of the polar regions and Greenland, with quasi-quad (QQ) polarization imagery with- 6m x 8m spatial resolution data over North America lands, and S-band data primarily over India along (Figure 2). The NISAR observation plans have not been finalized, but in general, the amount of data collected by NISAR will be a function of the satellites on-board capacity (i.e. power availability, data storage, downlink bandwidth (35 Tb/day), thermal considerations), the collection modes (i.e. resolution, polarization diversity) and the ground segment (i.e. the number of downlink stations). Each of these elements are important because the instrument maturity is at the stage where design of the hardware to be launched cannot be changed without significant impact to mission cost and schedule. In contrast, changes to the ground segment, including downlink capability at this point in time would not significantly impact mission schedule, though would add cost for downlink, transfer, processing, and storage for added downlinked data volumes (Figure 3).

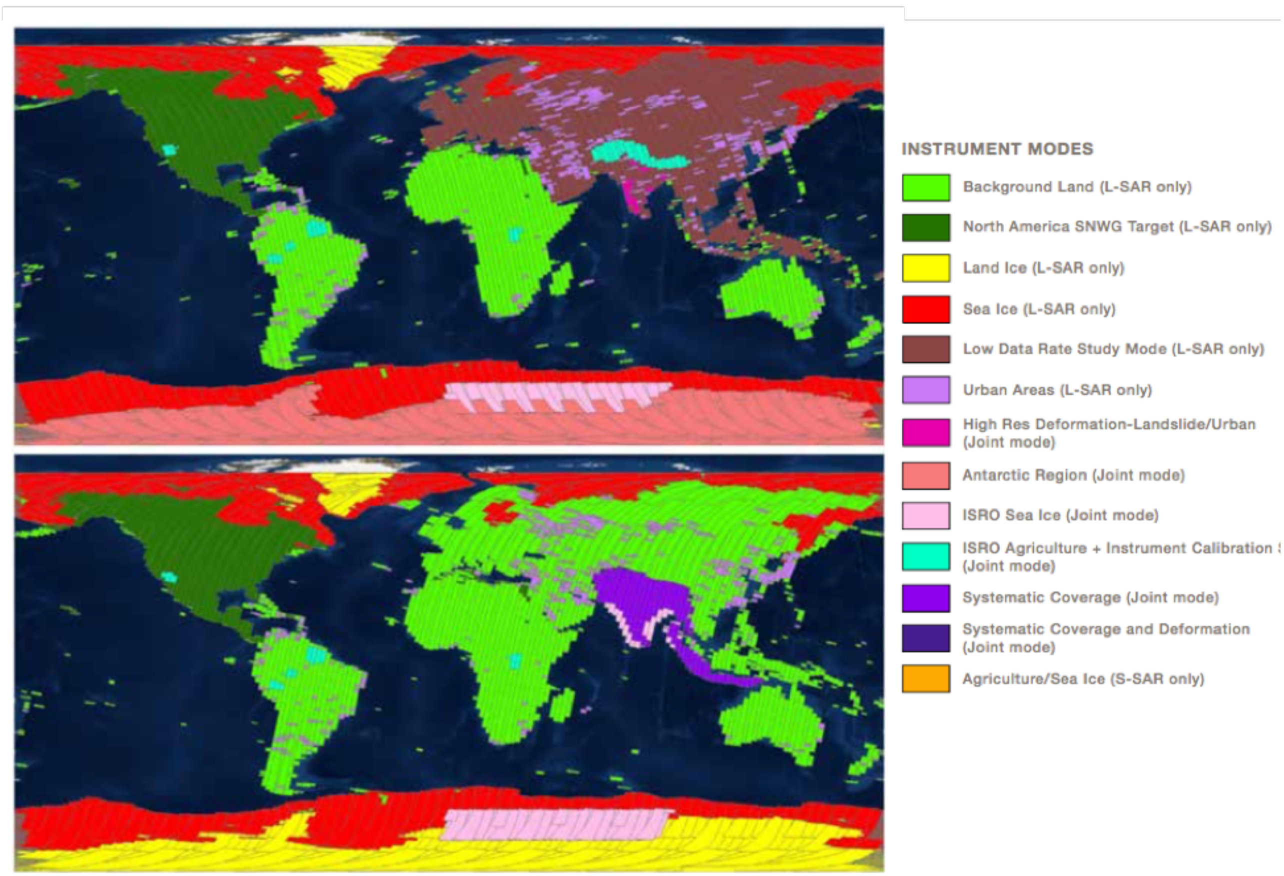

Figure 2 – Near-final mission observation plan. Revisions that increase data volume will require additional ground stations for increased downlink capability.

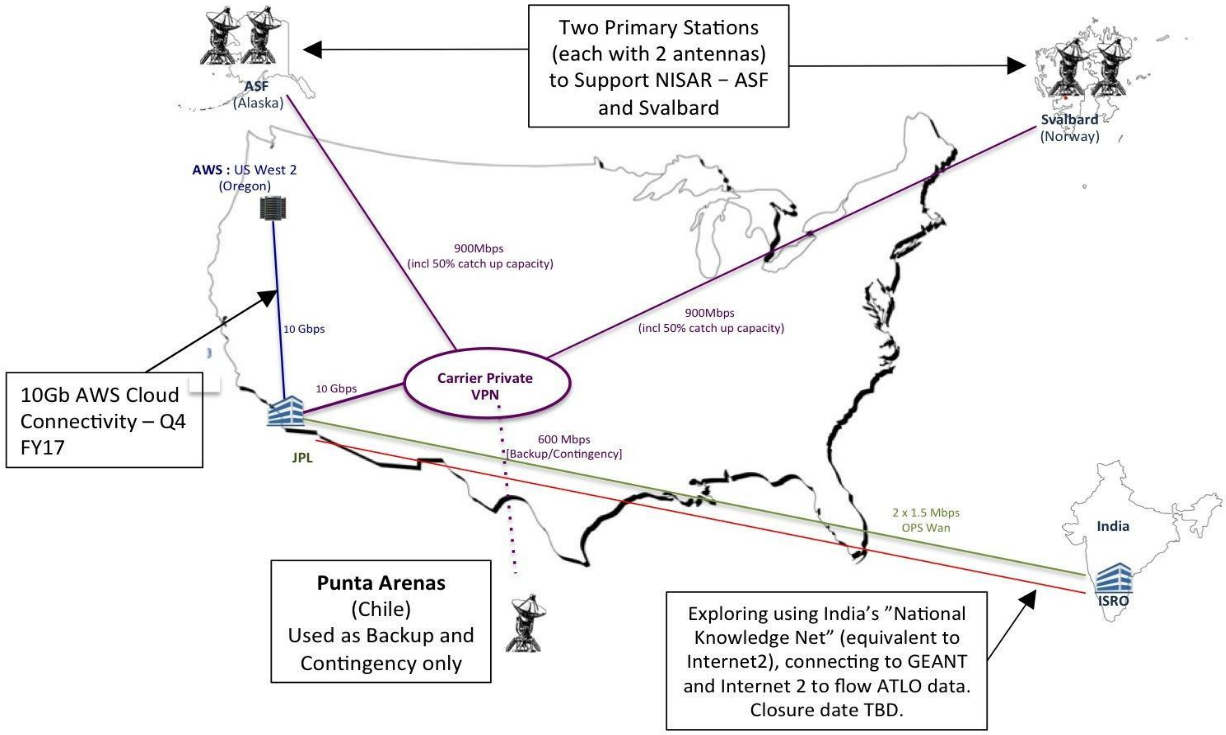

Figure 3 – Current ground station network envisioned for NISAR. Data transfer between the downlink stations and the processing centers is also shown. Processing will be done at ISRO and at a center in Oregon, with U.S. transfer funneling through JPL.

Table 2 – Near-final list of the standard NISAR data products to be delivered within 2 days of acquisition. The range-doppler SLC, a product that is posted in the radar reference frame (i.e., not geocoded), is the base-level (Level 1, or L1) product from which all others are derived from.

Product	Scope	Description
Range-Doppler Single Look Complex (SLC)	Global and all channels	Standard L1 product that will be used to generate all higher-level products
Geocoded SLC (GSLC)	Global and all channels	Geocoded SLC product using medium orbit ephemeris (MOE) and a DEM.
Geocoded Nearest-Time Interferogram (GIFG)	Everywhere. Nearest pair in time and co-pol channels only.	Geocoded interferogram with interferometric phase and coherence.
Geocoded Nearest-Time Unwrapped Interferogram (GUNW)	Everywhere. Nearest pair in time and co-pol channels only.	Geocoded multi-looked unwrapped differential Interferogram.
Polarimetric Covariance Matrix (COV)	Everywhere. All channels. All pols including single pol.	Backscatter product in Range-Doppler coordinates.
Geocoded Polarimetric Covariance Matrix (GCOV)	Everywhere. All channels. All pols including single pol.	Geocoded backscatter product in Range-Doppler coordinates.

3.4 NISAR Products and Latency

All NISAR data will be processed into a set of standard polarimetric (PolSAR) image and interferometric SAR (InSAR) data products (Table 2) by the NISAR project team. These data products are expected to be available 24-48 hours after observation. The standard products include polarization-dependent images, interferograms, and interferometric coherence. The latter two can be used for change detection and for measurement of surface displacement.

In addition to the standard acquisition and processing stream, an urgent response capability will be available through which lower latency products can be made available. The details have not yet been worked out, but the goal is to deliver the products listed in Table 2 with <12-hour latency following acquisition when urgent response acquisitions are initiated. For urgent response, one of the most important parameters is the latency between when an event occurs and when the data products can be delivered. This 'latency' is different from the typical latency defined for SAR data processing (and specified above), which is the time between when the image is acquired by the instrument and when the products are delivered, and encompasses data downlink, transfer, processing to form products, and product delivery to an archive. The time between when an event occurs and when the next NISAR image of the area can be made depends upon when the next pass of the satellite over the event location occurs and varies within the period for coverage considering that the area could be imaged on either ascending or descending orbits. At continental U.S. latitudes, there is a 77% probability of imaging any location within 4 days of a disaster.

4 NISAR's Applicability to Wetlands Management

Wetlands provide critical ecosystem services threatened by anthropogenic pressure (e.g. water diversion, urban encroachment) and climate change (e.g. changes in precipitation and temperature patterns, and sea level rise). To counter or adapt to these threats, governmental institutions and other organizations have established research and management plans to preserve wetland resources. Traditionally, the research and decision support tools rely on Landsat or high-resolution optical data, while the use of Synthetic Aperture Radar (SAR) for wetlands monitoring has lagged due to lack of consistent time series imagery. This is changing given the free availability of Sentinel-1A & B and the planned launch of NISAR in early 2022.

There are multiple driving policies that mandate the monitoring and reporting of wetlands within the US. The US Emergency Wetlands Resources Act of 1986 (P.L. 99-645, as amended) required the Secretary of the Interior, through the Director of the Fish and Wildlife Service, to map and digitize wetlands of the U.S. and to archive and distribute the data. The act also requires the Secretary to produce national wetlands status and trends reports to Congress. The Clean Water Act authorized for wetlands mapping to provide information to States to assist in the development and operation of programs under the Act. The Fish and Wildlife Coordination Act authorized the Secretary to provide assistance to, and cooperate with Federal, State, and public or private agencies and organizations in the protection of all species of wildlife and their habitats and to make surveys of lands and waters of the U.S. and to accept funds for purposes covered in the Act. Key to many of these policies, there is a need for wetland inundation mapping, a core objective of the NISAR mission.

The NISAR wetland inundation mapping, a core objective ensures every wetland around the Earth is imaged 4 to 6 times per month and with a spatial resolution of about 10 meters. NISAR data products are expected to be available 24-48 hours after observation. These ‘game changing’ observations will form the foundation of the evolving Level-1 (radar observation) and Level-2 (thematic) science requirements and accuracy benchmarks for wetland inundation themes. Notably, there are other observation of value to the wetlands application community, beyond inundation extent, for which NISAR data may be useful. NISAR, with its repeat-orbit, will enable precise (~1 cm) measurements of relative changes in water surface level every twice every 12 days, globally with ascending and descending imagery. This is done through a technique called radar interferometry. Hydrology, with climate variables, are dominant drivers of ecosystem productivity and phenology. Thus, we expect the impact of the water-level change measurement on science to be significant, advancing our understanding of wetland hydrology, water mass balance, and transport of sediments, carbon, and nutrients. NISAR, in addition to providing these important hydrological measurements, will enable monitoring of seasonal trends in wetland productivity and phenology, thanks to the radar backscatter, which increases with above-ground biomass (this holds for emergent plants only).

5 Wetland Applications Agency/Organization Overview

This workshop was focused on understanding the information requirements of representative agencies and organizations that can help bridge the gap between the low-level data that NASA provides and the higher-level information needed by Wetland managers. There were two opening talks, one presented by the Fish and Wildlife Service (FWS) and the US Geological Survey (USGS). There were subsequent talks by each of the relevant agency departments and organizations participating; specifically:

- FWS: National Wetland Inventory (NWI)
- USGS: National Land Cover Database (NLCD)
- Bureau of Land Management (BLM)
- Ducks Unlimited
- National Oceanic and Atmospheric Administration (NOAA): C-CAP
- US Forest Service (USFS)
- World Resources Institute (WRI)
- Conservation International (CI)
- National Park Service (NPS)
- The Nature Conservancy (TNC)
- Environmental Protection Agency (EPA)
- Silvastrum Climate Associates

Each agency/organization was asked to make a presentation addressing the questions that were sent by the NASA team (Section 2.2.1). Approximately 15 minutes were allocated to questions and answers after each presentation.

5.1 Fish and Wildlife Service (FWS)

The US FWS has the mission to “Work with others to conserve, protect and enhance fish, wildlife and plants and their habitats for the continuing benefit of the American people”. It is organized by 13 programs run from Headquarters and implemented within 8 regional divisions/branches across the United States. The programs most relevant to the workshop are: Ecological Services, Fish and

Aquatic Conservation, Migratory Birds, National Wildlife Refuge System, and Science Applications. Ecological Services is responsible for the Endangered Species Act Administration, the Fish and Wildlife Coordination Act Administration, the National Wetlands Inventory Program, integrating remote sensing, and employs many environmental contaminants biologists. The Fish and Aquatic Conservation is responsible for restoring and enhancing fish and other aquatic resources, the National Fish Habitat Partnership, 72 Fish Hatcheries, fish passage/aquatic connectivity, and aquatic invasive species management. The Migratory Birds program is responsible for the Migratory Bird Treaty Act Administration, the North American Waterfowl Management Plan, which spans the US, Mexico and Canada and manages conservation of waterfowl and wetland habitats, the US Shorebird Conservation Plan, and conducting population surveys. The National Wildlife Refuge System is responsible for meeting the Wildlife First mission of the agency and consists of 567 National Wildlife Refuges and 38 Wetland Management Districts, over 36,000 Waterfowl Production Areas (WPAs), >850 Million acres of lands and waters, and the Partners for Fish and Wildlife Program, which provides technical and financial assistance to private landowners to improve/conserve habitat. Lastly, the Science Applications Program coordinates internal and external efforts for developing and applying science for conservation, coordinates internally with USFWS regions and programs, identifies large-scale research needs, and provides tools and information to support sound science.

5.2 US Geological Survey (USGS)

The USGS is a part of the Department of Interior (DOI) and is organized by Mission Area. Wetlands applications of NISAR have importance for each: Core Science Systems; Ecosystems; Land Resources; Energy and Mineral Resources; Natural Hazards; and Water Resources.

The Land Resources Mission area includes the National Land Imaging (NLI) Program. NLI delivers a national and global capability to ensure broad public and scientific availability of observations of the Earth's land surface. Specifically, NLI creates and preserves a long-term record of the Earth's land surface at local, regional, and global scales. NLI expands scientific understanding and application of remotely sensed data to government and private users nationally and globally. NLI supports decision makers and policy officials in fulfilling their public responsibilities and informs national decisions about meeting current and future needs in land science and land observation. Lastly, NLI coordinates and integrates civil Earth observation with other sources of data including commercial and National Security space systems. To advance these activities, NLI developed a formal user needs process. This process documents user needs and compares them to imaging capabilities to inform mission architecture, imagery program and product development. NLI also supports national Earth observation assessments and identifies opportunities for technology investments and science collaboration. The process includes program and project level assessments to identify fundamental observables and their temporal, spatial, and spectral requirements along with other attributes. System independent observation needs can then be matched to any applicable observing system solution, whether optical, thermal, radar, etc.

USGS radar applications include projects that use multiple sources of land imaging (and other) data in combination. Of note are the Alaska permafrost and lake dynamics studies, the validated Level-3 Landsat Science Product Dynamic Surface Water Extent (DSWE), the land carbon dynamics project, active volcano assessments and eruptive potential research, and storm surge/coastal inundation. The

LANDFIRE project has also used radar data from PALSAR for some products and is actively evaluating the use of other radar sensors in the near future for mapping in Alaska.

NISAR inundation and water-level related products will have value for, and benefit from the USGS DSWE Level-3 Landsat Science Product. The goal for DSWE is to detect whether surface water is present in any cloud-, cloud shadow-, or snow-free pixel in the Landsat archive (TM class instruments and newer). The DSWE record can be used to formulate more complete wetland masks for NISAR wetland inundation assessments, while NISAR's L-band SAR data can be used to validate DSWE inundation detections as as each new Landsat scene is acquired.

The USGS is using the user needs assessment to identify potential early engagers with NISAR based on observables requirements and the derived information that NISAR can best provide (e.g., soil moisture, surface deformation, surface water extent, and vegetation structure) including a cross reference with the spatial and temporal resolutions needed. From this analysis, about 80% of the needs are met at a minimum level by NISAR, 66% are met at the breakthrough level, and 53% of needs are met at the target level. Areas of opportunity for NISAR were coastal wetland ecology, land carbon dynamics/ecosystem carbon storage, winter cover crop mapping, vegetation height/structure for fire fuel assessments, post-fire recovery, wildlife studies, soil moisture for drought assessment and monitoring, irrigation/consumptive water use, hydrologic modeling, wetland change monitoring, and land-ice dynamics.

The goals for USGS are to identify derived products that can be consumed by non-radar experts (outside typical communities of use), explore existing or new ways to collaborate in developing or extending applications, products and workflows, explore integration with other data instruments and platforms such as Landsat, international and commercial satellites, advocate for the early involvement in product definition, development, and validation, and provide education and training.

USGS collaboration mechanisms vary by program, but typically include science partnerships, technology transfer to commercial development, memorandums of understanding, international assistance, and cooperation with American Indian and Alaska Native governments.

5.3 FWS: National Wetland Inventory (NWI)

The FWS NWI is the principal U.S. federal entity tasked with providing information to the American public on the extent and status of U.S. wetlands. The FWS is required by the U.S. Congress to provide decadal reports on wetland acreage and change, produce the Wetlands Status and Trends Reports, and map wetlands of the United States in the National Wetlands Inventory (NWI) geospatial dataset.

The FWS lands include all wetlands in the United States including Hawaii, Alaska and territories. Wetland areas are variable and can be either vegetated (emergent/herbaceous, shrub/scrub, and/or trees) or open water. The hydroperiod or water regime, and vegetation phenology also vary. They can be proximal to infrastructure and may be linear, channels, or cover a wider area.

FWS NWI routine monitoring includes wetland acreage and change in the Wetlands Status and Trends Reports and the NWI. Wetland Status and Trends has the goal of determining the status and trends of U.S. wetlands and produce comprehensive, statistically valid acreage estimates of the Nation's wetlands. The FWS implements a decadal sampling protocol (NWI) actuated manually in

5,048 4mi^2 plots across the contiguous U.S. using very fine resolution (~1m) optical imagery. This method has been consistently executed since the 1950s. These reports have influenced all wetland policy forged by Congress and been used to determine the success of such mandates (e.g., "No Net Loss" policy). As such, the Status and Trends Reports are the yardstick used to measure the results of billions of dollars-worth of policy actions – as well as the effects of other change drivers.

FWS NWI does not have a disaster response mandate.

The remote sensing capability of the FWS relies on the use of high-resolution (1-5 m) optical imagery, combined with digital elevation models (DEMs) and the Soil Survey Geographic Data Base (SSURGO). The NWI manually interprets of fine spatial resolution (≤1-5m) optical images in a GIS graphical user interface and relies on additional ancillary data such as DEMS and SSURGO as well as automated classification techniques (e.g., eCognition). The classification system relies on at least 800 highly detailed codes based on information such as adjacency to deep water, morphology, water depth, vegetation structure, phenology, soils, and hydroperiod. More details can be found in FWS documentation FGDC-STD-015-2009.

The biggest challenges for FWS NWI is that changes in wetlands can be any size and monitoring these changes is challenging particularly in vegetated areas.

The value of NISAR will be in providing high resolution wetland mapping in vegetated areas and at high latitudes (e.g., Alaska). NWI relies on the long-term consistent methodology to track changes, so integrating NISAR could only be used as ancillary data for the established protocol. Specifically, NISAR data could be easily ingested as a time-series product of hydroperiod (i.e., inundation and soil moisture) or plant structure/biomass with low or at least well understood levels of uncertainty. Such products could be incorporated at three primary decision points: 1) targeting of resources, 2) production of new data, and 3) updating of existing data. Although identifying wetlands in vegetated areas is of value to NWI, they have no money or capacity to produce such a product, but they can provide calibration and validation data for others who are working to produce such a product.

5.4 USGS EROS: National Land Cover Database (NLCD)

The USGS Land Resources mission is to deliver data, research, and investigations that improve understanding of landscape-scale processes affecting resources of interest to the DOI, it's bureaus and their partners. Specifically, under the Land Resources Mission Area, the EROS Center has the mission to: 1) serve as the world's primary source for land remotely sensed images of the Earth., 2) be authoritative providers of land change science data, information, and knowledge, 3) serve as leaders in understanding how changes in land use, cover, and condition affect people and nature.

The USGS is a part of the Department of Interior (DOI), which manages 20% of the US land surface spanning the Arctic in Alaska to the southern tip of Florida, and from Midway Island in the Pacific Ocean to the Virgin Islands in the Caribbean. Therefore, DOI manages 500 million acres of lands primarily located in the western states and 1.7 billion acres on the Outer Continental Shelf. The lands include an enormous diversity of forest types, wetland, shrub land, savannah, tundra, mangroves, sage brush, riparian, cactus, etc.

USGS EROS routine monitoring includes land cover, which classifies 16 classes and provides percent tree cover and percent impervious surface, over the continental United States, Hawaii, and

Alaska. The NLCD is a Landsat-derived 30 m suite of land cover products, updated every 5 years (since 2001) and covers the United States. It is created by multi-Federal partners through the Multi-Resolution Land Characteristics Consortium. Specifically related to wetlands, the NLCD has two classifications: woody and herbaceous. Woody wetlands are areas where forest or shrubland vegetation accounts for greater than 20% of vegetative cover and the soil or substrate is periodically saturated with or covered with water. Emergent Herbaceous Wetlands- Areas where perennial herbaceous vegetation accounts for greater than 80% of vegetative cover and the soil or substrate is periodically saturated with or covered with water. The accuracy in classifying woody wetlands is 54% user accuracy (2001 and 2011) and 72% producer accuracy (2001 and 2011) and for herbaceous a 54% (2001) and 51% (2011) user accuracy and 59% (2001) and 57% (2011) producer accuracy. Important landscape-scale observations that would significantly address the most challenging problems in the NLCD include dominant vegetation structural features, surface water extent and wetland dynamics at 30 m spatial resolution consistently observed over enough spatial extent to cover major ecological landscape features.

USGS EROS does not have a disaster response mandate for the NLCD product.

The remote sensing capability of USGS EROS for NLCD primarily relies on Landsat data and training GIS data layers of landcover and impervious surface. The NLCD uses the NWI and Wetland Potential Index as ancillary input to generate the wetland classification.

The biggest challenges for USGS EROS with respect to NLCD are observing wetland soil moisture and its impact on carbon accounting. Specifically, the sub-canopy water levels would complement efforts for observing both wetland status and classification as it would inform wetland dynamic processes.

The value of NISAR will be improving monitoring of wetland dynamics, providing sufficient data for wetland characterization, and reducing biases in wetland mapping. Important for NLCD will be in using the 10-15 m data to inform the fractional wetland cover estimate. The value to NLCD will be in providing analysis ready data, defined as consistently processed to the highest scientific standards and processed to a level for direct use in applications – i.e., radiometrically corrected, geometrically corrected, and terrain corrected with standard precision reported. Furthermore, NISAR data will be important for NLCD to improve not spatial resolution but also temporal resolution. The NISAR data will also improve the change detection for NLCD, especially in many locations where cloud cover usually limit the ability for more frequent update the product, and potentially reduce the update cycle from current 5-year to a much less time cycle.

5.5 Bureau of Land Management (BLM)

The BLM mission is to sustain the health, diversity, and productivity of America's public lands for the multiple use and enjoyment of present and future generations. To meet this mission the BLM is mandated to manage public lands for multiple purposes including recreation, grazing, mining, energy development, and timber harvesting as well as protecting natural, cultural and historical resources.

The BLM manages over 245 million surface acres and 700 million sub-surface acres, which equates to more than 10 percent of the United States' surface and 30 percent of the nation's minerals and soils. Most of this area is in the western United States. The BLM also manages “special units” that are part of the National Conservation Lands System. Within the lands BLM manages, they work with wetlands of multiple sizes, morphologies, temporal dynamics that span a range of hydroperiods (perennial, ephemeral, etc.), vegetation types and structure vary as well as cover (i.e., some are open water, some are not) and phenologies. There is infrastructure present on some of the wetlands.

The BLM routine monitoring includes the Assessment, Inventory and Monitoring (AIM) program that is conducted annually. As part of this program, standardized monitoring for wetland spatial extent (perennial and seasonal), water quantity and quality, and vegetation cover, type and structure are currently being developed. These observations are linked with fish and wildlife species data and restoration management data layers.

The BLM disaster response mandate is to provide support for disasters impacting bureau land and resources, such as wildfire events, but has not operationally done so for wetlands. Wetland disaster response (flooding, drought) is implemented on an event by event basis, and could involve delineating impacts to water and vegetation quantity and quality. For BLM disaster response latency of information could vary from 1 week to 1 month, based upon the extent of impact to lands/resources.

The remote sensing capability of the BLM includes use of multiple remote sensing systems for addressing wetland resource management questions (e.g., water cover extent, vegetation type and structure, etc.). Typically, what is used includes aerial photography, SAR, LIDAR, and Unmanned Aerial Systems (UAS) with commercial multi-spectral imaging systems. Use of these assets includes both monoscopic and stereoscopic imagery. Although the BLM utilizes SAR to assist in reaching management objectives, it has been used in limited capacity. The ability of BLM to integrate new datasets into its decision support system to address resource management questions has continued to increase, however, this integration has neither been seamless, nor fully realized.

The biggest challenges for BLM for incorporating remote sensing datasets and tools have been in making those resources accessible to field personnel. First, data processing and exploitation tools must be made available to BLM field personnel. Second those in the field must possess technical proficiency to effectively leverage those tools to meet resource management objectives. Specific to the latter challenge, the learning curve for using remote sensing data like SAR and derived products can be steep, thus senior BLM technical leadership would need to provide guidance, training materials, and examples demonstrating how this information could be used to realize resource management objectives.

The value of NISAR will be in providing cloud free, multi-temporal imagery, which can support AIM program monitoring, and facilitate observations of water and vegetation cover trends through seasons regardless of time of day or weather conditions. Specific observations of value for BLM wetland applications that can be derived from polarimetric and interferometric SAR include the delineation of water cover extent and temporal trends, the characterization of biomass, soil moisture, and vegetation cover, type, and structure. Although, landscape scale analyses are going to be more feasible and functionally appropriate at present, the goal is target mapping with a target mapping unit of 0.1 acres. For these observations, any GIS-ready (e.g., GeoTiff) formats are most desired as BLM uses ArcGIS.

5.6 Ducks Unlimited

The Ducks Unlimited mission is to conserve, restore, and manage wetlands and associated habitats for North America's water fowl. To fulfill their mission, they need to know wetland extent, protection and change and work with both the FWS, Canadian Wetland Inventory, and Ducks Unlimited de México.

Ducks Unlimited lands include all wetlands in North America from open water to forested, from small pothole to large estuarine, and from ephemeral to permanent.

Ducks Unlimited routine monitoring covers some areas where management agreements are in place with farmers to keep water on the land for habitat. In the past, these areas were monitored using field visits, but now Ducks Unlimited uses optical imagery on a yearly basis. More broadly across North America, the goal is to observe inundation extent, inundation depth, vegetation cover, species composition, and loss on a 5-year basis.

The Ducks Unlimited disaster response mandate is primarily in the form of a restoration perspective post disaster event. For example, after Hurricane Katrina Ducks Unlimited helped with the coastal marsh restoration along the Gulf Coast. For restoration purposes, it is necessary to identify loss of habitat, potential restoration sites, and potential areas for mitigating future events.

The remote sensing capability of Ducks Unlimited is high as they use optical, SAR, and LIDAR data. For mapping water extent, they rely on Landsat and Sentinel C-band radar. For supporting the FWS NWI, they use 4-band digital aerial photos, LIDAR, and are experimenting with PALSAR. For the Canadian Wetland Inventory, they use Landsat, RADARSAT, and PALSAR. For mapping wetlands for the Ducks Unlimited de México, they use Landsat.

The biggest challenge for Ducks Unlimited is generating an automated approach to wetland extent and classification monitoring for North America. Specifically, how a wetland is defined varies and there are many different types of wetlands. For example, the FWS for the NWI defines a wetland as an area that is inundated within the root zone for at least two weeks of the growing season. Furthermore, there are many different types of wetlands that make it difficult to automate classifications. Ducks Unlimited classifies 19 classes (less than the NWI) and even this results in a semi-automatic classification.

The value of NISAR will be in the availability of L-band radar that covers North America and the alignment with optical imagery. Key to these images will not only be in the datasets themselves, but an approach for automating wetland mapping and monitoring. Although the NWI mapping process uses optical and lidar, it is really tricky in bogged areas, and this is where NISAR could be really useful.

5.7 National Oceanic and Atmosphere Administration (NOAA): Coastal Change Analysis Program (C-CAP)

The NOAA C-CAP mission aligns with the broader missions of NOAA, the National Ocean Service NOS) and the Office for Coastal Management (OCM), which is to understand and predict changes in climate, weather, oceans and coasts; to share that knowledge and information with others; and to conserve and manage coastal and marine ecosystems and resources. To meet this mission, the NOS provides data, tools, and services that support coastal economies and their contribution to the national economy. NOS is dedicated to advancing safe and efficient transportation and commerce through preparedness and risk reduction, stewardship, recreation and tourism. Within NOS is the OCM, which includes the National Coastal Zone Management Program, National Estuarine Research Reserves, the NOAA Coral Reef Conservation Program, and the Digital Coast.

The C-CAP lands include coastal areas (around oceans and the Great Lakes) covering 25% of the contiguous United States, American Samoa, Guam, and the Commonwealth of the Northern Mariana Islands.

C-CAP routine monitoring provides regional land cover maps every 5 years since 1996 with granularity/specificity of classification between that provided by the FWS NWI (detailed) and the NLCD (coarse). The classification includes woody wetlands (Palustrine Forested Wetland, Palustrine Scrub/Shrub Wetland, Estuarine Forested Wetland, and Estuarine Scrub/Shrub Wetland), herbaceous wetlands (Palustrine Emergent Wetland and Estuarine Emergent Wetland), Palustrine Aquatic Beds, Estuarine Aquatic Beds, Unconsolidated Short and Open Water. There are three resolutions of observations made: 30-m, 10-m, and 1-m. The 30-m pixel resolution product is based on Landsat imagery and the high-resolution landcover is based on optical imagery and Lidar (1 to 4-meter). The high-resolution products are only available in the Pacific, Caribbean, and project areas and a change product is not produced everywhere. For the high-resolution products, the NOAA vision is to initially provide 1-m landcover in 6 categories (Level 1) of impervious, bare ground, grass, shrub, tree, and water for restricted use (NOAA only) as there are some limitations to accuracy and quality. In the refinement phase, NOAA will provide 1-m land cover mapping with no licensing restrictions, address limitations from automation, provide 6-20 categories (Level 2). This phase is funded by NOAA or through cost-share with partners (e.g., Fugro, Ecopia, Earth Define, Quantum Spatial, Descarte Labs, and Tetra Tech). All products are consistent and accurate as per the Federal Geographic Data Committee (FGDC) National Geospatial Data Asset (NGDA) Management Plan.

NOAA C-CAP does not formally have a disaster response mandate.

The remote sensing capability of the NOAA C-CAP relies on aerial and satellite optical and LIDAR data. Typically, they use optical imagery during leaf-on and leaf-off seasons and during low tide. There is some remote sensing expertise in house, but with a small team of staff. Larger task orders are contracted to the private sector via NOAA's Coastal Geospatial Services Contract Indefinite Delivery/Indefinite Quantity (IDIQ).

The biggest challenges for NOAA C-CAP include accurately mapping palustrine forested wetlands and accurately capturing change in wetlands. Palustrine forested wetlands are particularly challenging because the canopy obscures the ground and there are issues with the time of available imagery (most satellite imagery is obtained in the AM). Capturing change in wetlands is challenging because of ditching and draining, annual variability in moisture (i.e., wet vs dry years), identifying restoration locations and effects of change on salinity.

The value of NISAR will be in increased canopy penetration and longer, more robust temporal time-series of variability in structure and moisture. NISAR may also provide information for other landcovers that C-CAP maps and potentially even species-level mapping and/or invasive species monitoring.

5.8 US Forest Service (USFS)

The USFS has the mission to sustain the health, diversity, and productivity of the 193 million acres of national forests and grasslands in the United States to meet the needs of present and future generations. This translates into the motto of *caring for the land and serving the people*. USFS carries out its mission under an ecologically informed, sustainable, multiple-use management concept and has the world's largest forestry research program, which informs its management practices. The USFS manages lands across the country including in Alaska and Puerto Rico. Organizationally, these lands are divided and managed by 154 forest and grassland administrative units across 9 different regions, while headquarters in the Washington Office provides national direction.

Today the agency faces challenges to some of its natural resources monitoring and management programs due in part to a changing climate, which has resulted in fire seasons that are on average 78 days longer than in 1970. From 1995 to 2005, the portion of the USFS's annual appropriated budget going to fire increased from 16% to over 50%. As more and more of the agency's resources are spent each year to provide the firefighters, aircraft, and other assets necessary to protect lives, property, and natural resources from catastrophic wildfires, fewer and fewer funds and resources are available to support other agency work. The agency has continually worked to do more with less, seeking to provide for the forests and grasslands' multiple uses with fewer resources and staff. With fewer "boots on the ground", remote data collection is an increasingly appealing option for gathering the key information needed to inform land and watershed restoration management decisions.

The USFS manages lands across the United States including Alaska and Puerto Rico, spanning bottomland hardwood forested wetlands in the temperate Southeastern US to high elevation fens, high-latitude vernal pools, and extensive carbon-rich peatlands. These lands are managed locally by ranger districts within the National Forest System. Other branches of USFS working on wetland management include Research and Development, International Programs, and State and Private Forestry. Of particular relevance for wetland information needs are natural resource specialists and managers that make decisions on watershed and land improvement investments.

USFS routine monitoring over wetlands includes data from multiple sources, including from local or regional monitoring, from the national staff in Watershed, Fish, Wildlife, Air, and Rare Plants, Rangelands Management and Vegetation Ecology, and the Geospatial Technology Applications Center (GTAC), and from other federal and non-federal partners (e.g. the FWS NWI). Most regions have regional remote sensing labs, although capacity in the regional labs can vary greatly, and most if not all national forests and grasslands have GIS specialists/coordinators. USFS monitoring of wetlands is not coordinated at the national scale and not all forests have monitoring programs. Of the national forests that do have routine wetlands monitoring programs, approaches can vary greatly. Generally speaking, wetlands are not routinely monitored in most USFS regions, highlighting an important data gap. Some of the national wetland reporting mechanisms and requirements are outlined in the 2012 Planning Rule, the Watershed Condition Framework, the National Best

Management Practices Monitoring Program, and Groundwater-dependent Ecosystems Inventory Field Guide. Due to the diversity of wetlands that can be found on National Forest System lands, the varied approaches to wetlands monitoring and availability (and quality) of data, consistent national reporting through mechanisms such as the Watershed Condition Framework remains a challenge. Decisions in the field are made using best available data at the time and local relevance (e.g. spatial scales that make sense and information that can be easily verified) is typically more important than achieving national or regional consistency. At the local unit level, available Terrestrial Ecological Unit Information (TEUI) mapping is heavily incorporated into wetlands management, where it is available. Not all national forests and grasslands currently have TEUI but most units are working toward having it. At the national level, to support the mapping of riparian areas, the USFS is currently working with the USGS to complete a national scale variable riparian areas map using readily available nationally consistent data products on streams and lakes from the USGS National Hydrography Dataset, high-resolution Digital Elevation Models (DEMs ~10 m resolution), landcover (e.g. NLCD and Cropland Data Layer), USGS 50-year flood height maps, the National Resource Conservation Service (NRCS) soils map (SSURGO), and the FWS NWI wetlands classification map. At the regional level, the southwestern region (Region 3) has been conducting aquatic riparian inventories using 4-band stereo imagery at 5 to 9 cm resolution. Scaling up these high resolution data collection efforts under growing budget constraints is a challenge.

USFS does not have a specific disaster response mandate with respect to wetlands, although if wetland areas were part of a wildfire event then they would be included under the umbrella of the agency's wildfire disaster response.

The remote sensing capability of the USFS is high yet variable. Areas of strength are GTAC, which has expertise in processing and packaging agency-tailored and relevant remote sensing and geospatial data for decision support, long-standing programs such as the Forest Inventory and Analysis (FIA), the regional remote sensing labs (although capacity at these labs can vary greatly), and collaboration with partner agencies such as direct work with the NASA Direct Readout Laboratory for near-real time download. Geospatial data is used at the national forest/grassland, regional, and national levels to help manage the work of the agency, but this data are also critically important in helping the USFS communicate and collaborate with its partners and the public. More detailed and spatially relevant data on wetlands and other resources is needed at the national forest/grassland level, while more synthesized information is needed at the regional and national levels. GIS-ready data are the most useful for management and decision-support applications, as is knowledge of whether the data products will have longevity and consistency over time (the long-standing Landsat program being a successful example of that).

The greatest challenges for USFS are in knowing where wetland, riparian, and groundwater dependent ecosystems are located, their condition (e.g. vegetation structure, composition, productivity, presence of invasive pests and diseases such as emerald ash borer), and the threats and stressors they face (e.g. changes in future state due to climate change). It is particularly challenging to inventory wetlands, either using remote sensing tools or field monitoring, in heavily forested areas. The USFS does offer capacity building to improve integration of mapping products into decision making, but technology transfer is a constant challenge. Key to technology transfer is relating remotely sensed data products to ground-based monitoring for validation and reconciling spatial resolution and scale capabilities of data products with the needs for decision support.

The value of NISAR to USFS for wetland applications will be in improving monitoring of groundwater dependent ecosystems, other wetlands and riparian areas. Improved monitoring of groundwater dependent ecosystems and of the different wetland types found on National Forest System lands, including riparian areas, will improve understanding of hydrologic regimes and functions over time, their susceptibility to anthropogenic changes, and the effectiveness of different management actions. The latency of NISAR can also enable the USFS to better study the value and importance of seasonal wetland ecosystems, such as seasonal ponds.

5.9 World Resources Institute (WRI)

The WRI mission is to move human society to live in ways that protect Earth's environment and its capacity to provide for the needs and aspirations of current and future generations. One of WRI's largest projects is Global Forest Watch (GFW), which empowers people everywhere with the information they need to better manage forests worldwide. GFW is convened by WRI, but represents a partnership of more than 100 organizations around the world.

The WRI monitors forest lands globally, which includes "wetlands" as mangroves and tropical peatlands. Maps of mangrove baseline extent and change detection are reported to end users as well as aboveground biomass and soil organic carbon. Maps of peatlands include baseline extent, emissions from peatland drainage due to plantation establishment, emissions from peat burning (provided by the Global Fire Emissions Database – GFED), and emissions from biomass loss (provided by Woods Hole Research center – WHRC).

WRI routine monitoring includes annual and near-real time (NRT) mapping. Annual maps of gross tree cover loss, emission from tree cover loss and gross tree cover gain (forthcoming) are provided, while NRT products include weekly tropical deforestation alerts, daily fire alerts, wind direction, and air quality. For example, GFW data shed new light on the very old problem of fires in Indonesia peat forests, thus helping to change public and political discourse and driving action on the ground. By repackaging and providing publicly available data (wind direction, daily fire alerts, air quality, concession boundaries), the GFW Fires platform enabled anyone to monitor the problem in NRT. Journalists used the GFW maps and data to report the story. The public became more aware and more engaged leading to boycotts in Singapore, thus bringing attention to the issue at the highest political levels. The governments of Singapore and Indonesia subsequently replicated the GFW system allowing Indonesia to reduce response time from over 30 hours to less than 4. Companies with concessions showing active fires could no longer ignore the problem, whether they were responsible for starting the fires or not, they had to join the conversation and seek solutions.

The remote sensing capability of the WRI is moderate as they typically collaborate with researchers to improve public access to forest and wetland information derived by the research from Earth Observations such as Landsat, MODIS/VIIRS, Sentinel 1 and 2, ALOS PALSAR, Planet Labs, and Digital Globe.

The biggest challenges for WRI are in big data management. Managing large, regularly updated data sets from NASA and researchers is an evolving process. The weekly Global Land Analysis and Discover (GLAD) deforestation alerts illustrate why it is challenging and how the system has evolved. GLAD uses large volumes of data, updated every week and the volume of data continues to expand as the system includes more countries and more datasets. At first, WRI converted the data to points within CART, but once GLAD supported Brazil, the files were too big. Then WRI created tiles in Mapnik and separated the analysis to run through ArcGIS Image Service. But keeping Mapnik and ArcGIS in sync proved difficult, and errors in ArcGIS were difficult to debug. Currently, WRI uses tiles for the visualization, but points stored in Elastic Search for analysis. As WRI continues to expand the alert system, it will likely have to keep improving the system to be reliable with these massive data volumes.

The value of NISAR for WRI will be in mapping baseline drainage canal networks, providing early detection of new peatland drainage to prevent illegal new planation development on peatlands, monitoring peatland restoration via changes in water level, and monitoring biomass change.

5.10 Conservation International (CI)

The CI mission is to empower societies to responsibly and sustainably care for nature, our global biodiversity, and for the well-being of humanity by building upon a strong foundation of science, partnership and field demonstration.

The CI lands cover strategic regions throughout the Americas, Africa, Asia and the Pacific. Although the focus of CI is on lands in these areas, they also invest and engage in the European Union, China, Japan, and the United States because of their profound influence on public policy, production, and consumption. The wetlands that CI works with are diverse and include coastal marine ecosystems that are vegetated (mangrove trees), marshes (grass and shrub), and seagrass that are both vegetated and in open water as well as Tonlee sap in Cambodia, which are both in open water and under trees, flooded forests, and Paramos in the Andes that are vegetated with shrubs.

CI routine monitoring of carbon stocks, tree height, degradation, and sea level rise (for blue carbon) occurs annually, while freshwater extent and condition occurs every 5-years. The annual reports are provided for National Determined Contribution. The Ecosystem Accounting every 5 years requires information on hydro-periods for flood pulse lakes and connectivity of wetlands, which can change month by month.

CI does not have a disaster response mandate, but is concerned with prevention. CI prioritizes ecosystem conservation and restoration, supports forest and wetland restoration activities and increases efficiency of water use and carbon emissions.

The remote sensing capability of CI is high, but there are other limitations to their use of remote sensing data. For Blue Carbon monitoring, CI relies on Landsat and Sentinel1 data for mapping mangrove heights and freshwater. CI does have technical staff in many of their international offices, but in general CI is understaffed and they no longer have a powerhouse lab filled with technicians. Furthermore, CI does not have high-end computing, so relies on strong partners to implement advanced computing. as their primary focus is on operational use of SAR data.

The biggest challenges for CI could be met with maps of seagrasses, mangrove change, paramos and ecosystem condition.

The value of NISAR for CI will be in observing interannual variability for improving Ecosystem Accounting and more accurate estimates of biomass as well as advanced monitoring of fringe ecosystems that disappear quickly.

5.11 National Park Service (NPS)

The NPS mission is to preserve unimpaired the natural and cultural resources and intrinsic values of the National Park System for the enjoyment, education, and inspiration of this and future generations. The National Park Service cooperates with partners to extend the benefits of national and cultural resource conservation, and outdoor recreation throughout the country and the world. The agency is organized under a director and two deputy directors, one for Operations and one for Management and Administration. Under Management and Administration there is the Information Resource Directorate that includes the National Information Services Division, which is responsible for supporting NPS data and software activities along with all technical project management and product development.

The NPS wetlands include non-tidal and tidal wetlands. Non-tidal wetlands include peatlands such as fens and bogs with wide spatial extent and ponds near the water table and lots of biomass accumulation, southern deep water swamps that are both wooded and have open water, inland freshwater marshes and meadows comprised of many soft-stemmed plants, variable water saturation and high spatial variability, and riparian wetlands that provide inland hydrologic corridors and are very botanically diverse. Tidal wetlands include salt marshes with many emergent plants around bays and river inlets, mangrove swamps that are both tropical and subtropical and dominated by salt-tolerant trees, and tidal freshwater swamps that have high vegetation variability. NPS wetlands have highly variable temporal dynamics such as hydroperiod and vegetation phenology and are not commonly located near infrastructure, but when they are it is important to map that.

NPS routine monitoring includes required inventories of geologic resources, vegetation mapping, water resources, vertebrates and vascular plants, soil resources, a natural resource bibliography, climate, a base cartography, and air quality. Required monitoring includes the health of ecosystems measured by "vital signs". Monitoring occurs within each park or program spatial extent with variable mapping units.

NPS disaster response mandate includes primarily hurricanes, floods, tsunamis, and other natural disasters. For these disasters, they require GIS-ready data layers related specifically to coastal and vegetation change. The required latency is as soon as possible.

The remote sensing capability of NPS primarily relies on optical imagery, LIDAR, and stereo imagery. These data are typically used for vegetation classification maps, wetland inventories, and wetland restoration projects. Data needs to be GIS-ready and only basic product development is supported.

One of the big challenges for NPS is monitoring wetland changes at the park scale, which need to be reported at least every 5 years for integration with the NWI. An additional challenge is in observing annual coastal event impacts on wetlands, which is used for identifying areas for restoration.

The value of NISAR to NPS will be in providing large-scale observables, frequent delivery with repeat observations, and potential information to improve decision support systems. Large-scale observations are needed to identify areas impacted and standardize high-spatial resolution data acquisition. Repeat acquisitions are useful for monitoring changes and are complementary to other repeat imagery (e.g., Landsat). Lastly, information derived from NISAR would be very useful for supporting restoration efforts and facilitating collaborations for wetland management across jurisdictions.

5.12 The Nature Conservancy (TNC)

TNC mission is to conserve the lands and waters on which all life depends. TNC helps create solutions that benefit people and nature that are grounded ins science. With respect to wetlands, their driving conservation concerns are chronic effect of human activities on water resources, including wetlands for habitat and water quality benefits, watershed episodic flood protection, and coastal flood and habitat impacts from inundation.

TNC lands of concern span at least the 119 million acres worldwide that they have helped to protect.

TNC routine monitoring includes information necessary as inputs to models used for deciding which wetlands to protect or restore. Model input attributes must provide information at a meaningful spatial scale, have credibility with partners, and compliment or link to a regulatory watershed model. Specifically, model inputs such as a digital elevation model, stream map, soil wetness, and riparian/floodplain slope are necessary to derive nutrient and sediment retention potential, a key parameter for eco-hydrologic models that provides maps of eco-hydrologically active areas and their function as it varies by seasonal weather and climate change. These models can be used for a number of applications such as predicting wetland hydroperiods and identifying coastal wetlands and transition zones. Key for parameterizing models is a longer record (at least 3 years, but 10 years is better).

TNC does not have a disaster response mandate.

The remote sensing capability of TNC uses LIDAR data and Sentinel 1 C-band data to parameterize the aforementioned models used for determining which wetlands to protect and restore.

The biggest challenges for TNC are engaging stakeholders to be involved in applying and interpreting the models.

The value of NISAR to TNC will be in complementing existing work to integrate Sentinel C-band data. Key for integrating any new datasets is that they must complement existing data record because it is necessary to have at least a 3-year record to adequately parameterize the models.

5.13 Environmental Protection Agency (EPA)

The EPA mission is to protect human health and the environment. By which, the EPA develops and enforces regulations, gives grants, conducts research, sponsors partnerships, teaches people about the environment and publishes information on environmental research. The EPA is organized by offices at headquarters with labs and research centers as well as10 regional offices that have a geographic focus. The Office of Research and Development and the Office of Water (which includes and Office of Wetlands and Watersheds) would be most likely to engage with NISAR before launch on wetland applications. The key research program of relevance to NISAR include the Safe and Sustainable Water Resources Research Program. Office of Research and Development laboratories and centers that are relevant for wetland applications of NISAR data include the National Center for

Environmental Assessment (NCEA), the National Exposure Research Laboratory (NERL), and the National Health and Environmental Effects Research laboratory (NHEERL).

The EPA develops and enforces regulations on wetlands in the United States. They do this through authority of the U.S. Clean Water Act to develop and implement federal wetland policy and programs, which include wetland permitting and mitigation, defining “waters of the United States”, setting water quality standards, and constructing wetlands for wastewater treatment. They also are responsible for ensuring compliance with the Clean Water Act, enhancing state and tribal wetland programs, conducting a National Wetland Condition Assessment, and leading the U.S. Interagency Coastal Wetlands Initiative.

EPA routinely monitors for the National Wetland Condition Assessment (NWCA), which is a national, statistically based survey of wetlands across the conterminous US. NWCA is part of the EPA’s National Aquatic Resource Survey and is conducted every 5 years beginning in 2011. The objective of the NWCA is to report on the ecological condition of the nation’s wetlands and stressors most commonly associated with poor condition. The approach surveys approximately 1,000 wetland sites every survey cycle, 1-2 times during peak growing season (May – September). Sites are selected using the NWI digital wetland map. The data collected at these sites include plant species presence, cover and height, soil, profile descriptions and chemical analysis to a depth of 100 cm, hydrology source indicators and stressors, water chemistry and habitat disturbance. Representative site data are then used to derive indicators of wetland condition and stress that are applied regionally and nationally for any given type of wetland.

EPA carries out disaster response and recovery under the National Oil and Hazardous Substances Pollution Contingency Plan and the National Response Framework. EPA disaster response addresses immediate health and safety needs of affected communities and is typically conducted on a weeks’ to months’ timeframe for any large scale event. EPA disaster recovery can last years and focuses on long-term restoration of places, resources, and communities affected by disaster.

The remote sensing capability of EPA is variable by office as GIS work is not focused in any one office. The Office of Mission Support (formerly the Office of Environmental Information) leads information technology work agency-wide, this includes the EPA GIS Workgroup, the Geographic Information Officer, and the GeoPlatform and Environmental Dataset Gateway. The Office of Research and Development leads research efforts including the Environmental Modeling and Visualization Laboratory and Safe and Sustainable Water Resources research into the use of satellite imagery to map and monitor aquatic resources nationwide. The EPA also partners with and leverages the expertise of other federal agencies including the US Army Corps of Engineers, NOAA, USGS, and the US FWS in these efforts.

Some of the biggest challenges for EPA are (1) misidentification of wetland sites by NWI for field verification and (2) a need for accurate national maps of surface waters for Clean Water Act jurisdiction and for other program implementation. For example, during the field campaigns for the NWCA, misidentification of field sites using NWI was costly, particularly a challenge in small, forest, and seasonal wetlands. Improved mapping would reduce costs by evaluating target sites prior to sampling. Improved mapping of surface waters and surface water dynamics (e.g., extent and stage) would also benefit Clean Water Act jurisdictional determinations, which determine the scope of wetlands subject to Clean Water Act regulatory policies and programs developed and enforced by EPA and the Corps.

The value of NISAR to EPA will be enabling improved wetland maps of forested and seasonal wetland systems because of the spatial resolution and the temporal repeat. The higher spatial resolution of NISAR will offer greater ability to delineate wetland extent, and to explore landscape dynamics associated with the relationships between wetland conditions and stressor indicators. Furthermore, the temporal repeat of NISAR will enable time series of information (e.g., soil saturation, inundation, and hydroperiods) that can be used to improve understanding of wetland hydrologic regimes. It is worth noting that although NISAR could provide value to EPA, the Office of Water (EPA's water policy office) and the water program staff in EPA's regional offices do not generally have the ability to process raw data, as such they would require GIS-ready products to enable use in wetland policy and program implementation. Specific products that would be of Agency-wide benefit for Clean Water Act and other programs include (1) up-to-date wetland maps (including vegetated wetlands); (2) improved detection of lakes, streams and riparian corridors; (3) automation of image processing to facilitate the transferability of tools to Regions, States, Tribes, and stakeholder groups.

5.14 Silvastrum Climate Associates

Silvastrum Climate Associates that has the mission to nurture sustainable development and restoration that is science based, action oriented, and community driven that is achieved by they providing technical support around the world, integrating with climate mitigation and adaptation ??? and translating science into management and policy. Specific to wetlands, Silvastrum Climate Associates provides services including sustainable development and restoration planning, financing, and implementation.

Silvastrum Climate Associates works internationally with lands in the United States and across Central and South America, western Africa, the Middle East, Southeast Asia, and Australia. Their work in wetlands cover coastal wetlands and mangroves with particular emphasis on Blue Carbon.

Silvastrum Climate Associates does not routinely monitor, but partners do and are particularly interested in where wetlands are the type of wetland, the carbon stock (biomass and soil), as well as coastal vegetation, flooding, and water levels as they vary throughout the year. Partners are particularly interested in monitoring carbon stocks at 3-5 year intervals at high spatial resolution in order to integrate observations into models. At present, water level is measured from gauges, but there is a need for remote monitoring in developing countries.

Silvastrum Climate Associates does not have a disaster response mandate, but after a disaster, key observations needed by their stakeholders (government agencies) include determining the impact of the event on system functioning and resilience, where the water goes, how natural infrastructure was impacted as compared to built infrastructure.

The remote sensing capability of Silvastrum Climate Associates primarily relies on processed and quality controlled remote sensing datasets. In particular, Silvastrum Climate Associates uses topography and bathymetry (derived from SRTM, SAR, and Lidar), land cover and land use change (derived from Landsat), wetland classifications and extent (from CCAP and derived from Landsat), and soils (derived from soil survey).

The biggest challenges Silvastrum Climate Associates are in providing information relevant for carbon monitoring in remote or low-resource areas. Information needed includes landcover and land use change, carbon stocks and greenhouse gas emissions, topography and bathymetry, infrastructure, water and soils, and flood extent. This information would be valuable for determining impacts of water flow and storage on infrastructure specifically with respect to changing water table depth and sea level rise, mapping water storage particularly in developing countries, improving understanding of the relationship between changing hydrology and ecosystem resilience, and determining soil moisture and surface water extent and salinity to improve quantification of carbon stocks and emissions (carbon dioxide and methane).

The value of NISAR to Silvastrum Climate Associates will be in providing data everywhere (especially in cloud covered areas like the tropics) that can be used for mapping landcover, and in providing sub-annual observations to capture information on water levels, methane emissions and plant productivity after events and seasonally.

5.15 Natural Resources Conservation Services (NRCS): Agricultural Conservation Easement Program (ACEP)

The NRCS: ACEP mission is to provide resources to farmers and landowners to aid them with conservation and their priority is to ensure productive lands in harmony with a healthy environment. The NRCS originally began as the Soil Conservation Service in 1935, but now has a broader mission of conservation. NRCS brings 60 years of scientific and technical expertise to the conservation industry and is directly involved with activities that help benefit soil, water, plants, air, and animals. Within NRCS, the ACEP provides financial and technical assistance to help conserve agricultural lands and wetlands. Under the Agricultural Land Easements (ALE) component, NRCS helps American Indian tribes, state and local governments and non-governmental organizations protect working agricultural lands and limit non-agricultural uses of the land. Under the Wetlands Reserve Easements (WRE) component, NRCS helps to restore, protect and enhance enrolled wetlands.

NRCS lands span the United States. Because 70% of U.S. land is privately owned, NRCS partnership with private landowners is critical; NRCS provides assistance to these landowners. Over the past 25 years, NRCS has worked with landowners to protect more than 4.4 million acres of wetlands and agricultural lands covering a diverse real estate portfolio. This diverse portfolio includes farmed or converted wetlands, former or degraded wetlands from agricultural practices, lands substantially altered by flooding, croplands or grasslands (minimum parcel enrollment size of 20 contiguous acres with hydric soils and water depth ≤ 6.5 feet), riparian areas around streams or other waterways, restored or protected wetlands, adjacent lands that contribute significantly to wetland functions, and unique or critical wetland complexes (e.g., Pocosins, prairie, potholes, playas, vernal pools, fens, bogs, and ridge and swale floodplain complexes). NRCS easements range from 0.1 - 15,000 acres in size. There are over 21,000 easements to date.

NRCS ACEP routinely monitors land in accordance with the Statement of Federal Financial Accounting Standards 29 (SFFAS 29), which considers easements held by the United States as Stewardship Lands that must be accounted for as part of the agency's annual financial accountability reporting. The SFFAS 29 requires annual reporting of the "Condition" of all Stewardship Lands. Condition of these lands is determined based on landowner compliance with the warrant easement deed. As such attributes of condition that are monitored depend on the types of unauthorized uses of that land. Examples of unauthorized uses include: mining (includes peat/gravel), cropping, haying/mowing, grazing (cattle, feeders, water troughs), burning, infrastructure development (buildings, hunting blinds, parked equipment, etc.), aquaculture, installment of impervious surfaces, hydrology alteration, timber harvesting, or development of trails and roads. Despite annual reporting, monthly or bi-monthly observations help determine site conditions such as soil moisture and inundation and wetland extent because of these unauthorized land uses. Currently, reporting is done within 2 weeks of fiscal year end using on-site and remote sensing.

NRCS ACEP disaster response mandate is to provide assistance for the Emergency Watershed Protection Program (EWPP). After natural disasters, if land condition impairs a watershed or poses a threat to life, health, or property, NRCS ACEP assists in removing threats and restoring the natural environment to the greatest extent practical. Assistant activities include sediment and debris removal, protection from additional flooding or soil erosion by retarding runoff, removal of debris deposited by a natural disaster that would affect runoff or erosion, and restoration to the maximum extent practical based upon pre-event conditions of the hydraulic capacity of the natural environment. Measures must also provide immediate, adequate, and safe relief from the hazard. On-the-ground reporting is most important for EWPP; however, large scale disasters often make it difficult to know where to focus limited resources and personnel. Satellite imagery of impact areas available within a week or two of disaster could greatly assist NRCS in focusing efforts. Before and after imagery would allow NRCS to direct resources to watershed locations with greatest damage and need for most immediate assistance. For this purpose, latency would between acquisition and delivery would need to be within 1-2 weeks.

The remote sensing capability of the NRCS ACEP primarily relies on use of digital high-spatial resolution optical imagery. In 2012, NRCS conducted a National Easement Assessment Project (NEAP) study with the University of Tennessee Institute of Agriculture to look at methods and imagery sources for ecological monitoring of attributes necessary for compliance monitoring. The NEAP study used 15 cm (0.15 meters or .5 ft) and 30 cm (0.30 meters or 1 ft) Ground Sample Distance (GSD), orthorectified, 4-Band (Red, Green, Blue, NIR), 8-bits per band (256 tonal values) optical imagery in GeoTIFF format. The NEAP study concluded that 15 cm ortho imagery was best for monitoring features relevant to Statements of Federal Financial Accounting Standards (SFFAS) condition attributes (e.g., grazing animals, fences, dumping (refuse and wastes), sewage, or other debris, animal waste, unimproved roads, firebreaks and bridges, water control structures, 10x10 hunting blinds, structures and cropping). The study also found that specific wetland sites needed to be visited separate of transect intervals for proper remote sensing ground truth data.

The biggest challenges for NRCS ACEP are in resolving soil moisture, inundation extent and wetland extent at the scale of each easement.

The value of NISAR to NRCS ACEP will be in providing GIS-ready information (derived from NISAR data) every 2 weeks that does not require on-site data storage.

6 Information Product Requirements

In facilitated discussions on the first and second day, there was unanimous community consensus on four Level 3 information products that could increase NISAR data utility across agency and organization (listed in order of priority): 1) inundation/surface water extent, 2) soil moisture, 3) wetland extent in vegetated areas, and 4) water stage change. A fifth product, soil state (frozen/unfrozen), was identified, but there was no consensus that this would be useful across agencies and organizations.

For an inundation/surface water extent product, the community converged on specifications of sub-30 m x 30 m spatial resolution and <2 week temporal resolution with 1-2 week latency. Such a product could be binary mapping pixels with water above soil, or preferably provide percent area of inundation within a pixel. Such a product would need to provide inundation confidence (as opposed to saturated) and be at least 10-15% accurate because that is what is possible with existing optical imagery (Landsat) during leaf-off. Although 1-hectare resolution would be sufficient, it is not desirable because wetlands are smaller. Ideally the product would align with existing 30 m x 30 m products (e.g., from Landsat), but in this case NISAR would only add value under canopy. The desired product would be at <2 week temporal resolution as wetlands are defined as being areas inundated for 2 weeks during growing season. Latency for delivering the product would be most useful for enforcement at 2 weeks and 1 week for remedial action after disaster or water resource management. The community commented that for calibration and validation of such a product, there are many farms with existing farm implements that measure soil moisture. Also of note, ***such a product should not assume to know where wetlands are, but rather map inundation/surface water extent everywhere.***

For a common soil moisture information product, the community converged on specifications of sub-hectare spatial resolution and monthly temporal resolution with 2-6 week latency. The product should provide volumetric soil moisture with a measure of uncertainty as a continuous variable of surface (top) soil moisture with 5-10% accuracy (to align with field-based measurements). The wetlands community is particularly interested in soil moisture as it relates to two thresholds: inundation and saturation. The best spatial resolution for such a product would be sub-hectare. The reason being that the 80-90% threshold of wetland sizes is a hectare, and these are the wetlands we already know. What is needed is a soil moisture product that can help detect those that aren't already being captured (<0.4 ha); wetlands we care most about are the vulnerable and dynamic wetlands that are smaller, drier and covered by vegetation. It is worth noting that community also agreed that remote sensing capability (i.e., pixel resolution) doesn't always work because in some places wetlands are circular not linear. For most wetland applications, soil moisture observations at monthly cadence are necessary to capture the interannual variability dynamics, but for disaster applications the product would need to be as often as possible. Such a product could employ both spatial (3x3 ~ 30 m pixel res) and (rolling) temporal speckle filters. Latency should be at least as good as can be provided from the program of record. For example, Radarsat provides 4 hour latency for delivering a value-added product after acquisition for flooding applications. For non-disaster response applications, e.g., classification, it can be longer (2-6 weeks), but in general, as soon as possible is best. Lastly, the community advised that for wetland applications, the product would need to be validated across a variety of different vegetation structures and soil types.

For a wetland extent in vegetated areas information product, the community converged on a minimum spatial resolution of 30 m x 30 m for an annual product needing 2-week latency of the data used to generate the product. Wetland is generally defined by characteristics of vegetation type, hydrology, and soil, however an operational definition is an area that is inundated or saturated in the rootzone for at least 2 weeks of the "average" growing season. The minimum acceptable spatial resolution for use is 30 m x 30 m. Because the separation between upland and saturated soil/flooded vegetation varies seasonally, but the wetland boundary does not vary, an annual time step for a wetland extent product would be sufficient. The desired latency for such a product would be two weeks. The community also noted that validating the product will require care as what is define as "true" wetland varies.

For water stage change, the community agreed on a 30 x 30 m spatial resolution every 12 days with a 2 week latency. Water stage change would be reported in meters with at least 1 cm accuracy. The spatial resolution should match existing products with 30 x 30 m pixels every 12 days. The community would prefer to have small gaps in the product rather than a poor signal to noise ratio to meet the temporal resolution. A latency of 2 weeks is necessary to meet the needs of water regulations.

For any of these products the wetland community specified desirable data formats and projection as well as a desire for algorithm documentation. Geotiff, National Imagery Transmission Format (NITF) or other native GDAL formats are desired using metadata standards in congruence with weather data. Although there are open-source solutions for parsing the changing format of HDF, updating existing infrastructure is cumbersome. Geotiff was therefore identified as the preferred data format because it can be readily ingested/processed by commercial remote sensing software (e.g., Imagine SAR processing module, ENVI Sarscape, Sentinel toolbox, ASF Map-ready, etc.). Although NITF is also desirable, this format may not be supported by existing freeware SAR processing/exploitation software. The desired projection would be UTM for local and latitude/longitude for global applications. However, whatever projection selected should align with what agencies already use (e.g., USGS -UTM, NLCD Albers 1983, or Landsat/Sentinel – MGRS, BLM – WGS84).

7 Suggestions for Increasing NISAR Utility for Wetlands Community

In a facilitated discussion on the third day, the community discussed solutions for increasing NISAR utility for the community between the workshop and NISAR launch. These included: 1) use of existing wetland community focus sites for calibration and validation, 2) providing tools and services for easy data access, 3) distribution of sample L-band data at a temporal resolution for understanding how to extract information for wetland applications given the highly variable temporal dynamics of wetlands, and 4) conduct of training workshops specific to fields of interest by agency that facilitate capacity building for users with limited SAR knowledge would be of enormous benefit.

For calibration and validation, there was a lot of interest in both pre-launch algorithm calibration activities and post-launch validation activities. For pre-launch activities such as the planned UAVSAR AM/PM campaign, there were a lot of calibration and validation sites discussed. Although many did not fall within the planned data collections, there was a need to follow-up and determine if there were sites that were underneath the planned flight route that could be imaged by ‘turning the instrument on” to collect additional data while in transit. Of particular interest to the community was the availability and access to NISAR-simulated data from the UAVSAR data collected during this campaign. There were additional discussions about a the planned ISRO L- and S-band airborne campaigns and whether the data would be made available. At the time of the workshop, data availability for this campaign was unclear. There was additional discussion emphasizing the importance of obtaining NISAR-like data from other UAVSAR flights (e.g., over international domains) where more of the variability in wetland types would be captured. For post-launch validation, the community suggested relying on the well-established long-term sites that already exist including those from NRCS and the EPA. ***Importantly, they noted that current requirements for the NISAR inundation extent mapping assume that we know where wetlands are, but we do not, especially in vegetated areas.***

Several specific tools and services were identified for easy access. One was access to scripts for processing desired time series data stacks (e.g., multi-band composite of polarized images) based on the user specified spatial and temporal resolutions (as well as user selected image pairs for InSAR). Another would be a user front-end Graphical User Interface (GUI) for extracting the desired spatial and temporal resolutions into a GIS platform. Services should enable both download of raw and processed data as well as the access to such via cloud computing (e.g., Google Earth Engine). For any tools and services provided, documentation on how to use them within a GIS/Remote Sensing processing software is desirable.

A UAVSAR campaign with 12-day repeat from which simulated NISAR data would be produced is needed to overcome the current lack of L-band data at a temporal resolution for understanding how to extract information for wetland applications. Access to simulated NISAR data from such a campaign could provide demonstration for capability of a national product. Collecting this data is not enough, there needs to be collaboration because federal agencies (e.g., FWS) have very limited funding for research and development. These agencies would need an information product that is already generated. In order to garner support for generating such information product an improvement on the current systems needs to be demonstrated. A big improvement would be considered a 10% increase over existing product accuracy (e.g., NLCD is ~55% accurate wetland classification). For demonstrating such improvement, it was suggested that a systematic approach be taken. All agencies have different regions and garnering support in each region at the individual park/refuge level will be important.

8 Roadmap to Launch

In the near term before NISAR launch (expected 2022), it was suggested that a Wetlands Applications Working Group (as per the specifications of the NISAR Utilization Plan) would be useful. Such a working group would focus on: 1) sites for calibration and validation of wetland application relevant information products, 2) strategies for gaining traction within the respective agencies and organizations for use of NISAR data, and 3) how to go from NISAR data to the needed information products (Section 6) for utility within the current agency and organization decision support systems.

Specific to strategies for gaining traction within the respective agencies and organization for using NISAR data, the community felt that the NISAR-like data would be useful, and that there need to be improved tools for communicating the value at different levels (i.e., land manager, program manager, etc.) within the wetland agencies and organization. The suggestion was to use the UAVSAR data in combination with the NISAR data simulator to demonstrate how NISAR could fit into the current wetland mapping tools. Of importance in these demonstrations is the improved efficiency and accuracy of the existing tools when using NISAR-like data, the sustainability of that integration through time, and estimation of the cost for integration. In particular, there needs to be cost-benefit analyses at the management unit scale to help provide justification both to the land and program managers. Participants agreed that although many of the agencies (USFS, EPA, FWS, USGS, and NRCS) need such demonstration studies, a cost-benefit analysis for one agency may be enough for the other agencies to make the case that such studies should be considered in the agency strategic plans. As such, demonstrations on different key/representative wetland areas/refugia could be conducted in areas operated by different agencies or organizations. Not only do the agencies need these demonstration studies, but there needs to be further discussion on how best to communicate these studies within the agencies and organizations beyond the members of the working group. The existing applications white papers that NISAR provides are good for those that are already aware of NISAR, but agency-specific communication materials would be highly beneficial.

In summary, workshop participants identified three key objectives for a working group to address in the years between now and NISAR launch, that would increase the utility of NISAR for the broader wetland communities.

9 Appendices

9.1 Agenda

DAY 1: Tuesday, October 23, 2018

7:30 - 8	*Arrival & Sign-In*	
Program and NISAR Overviews		
8:00 – 8:10	Workshop Welcome	Brad Knudsen, Refuge Manager (FWS)
8:10 - 8:20	Agenda Overview	Natasha Stavros (NISAR Deputy Applications Lead for Ecosystems)
8:20-8:35	NASA Welcome	Gerald Bawden, NISAR Program Scientist (NASA/HQ/Earth Science Division)
8:35 - 8:55	FWS Overview	Mike Higgins
8:55 – 9:15	USGS Overview	Greg Snyder
9:15 - 9:30	Discussion	
9:30 – 9:45	Break	
9:45 - 10:15	Wetlands Observations with Radar	Marc Simard, NISAR Science Team, JPL/CalTech
10:15 – 10:45	NISAR Mission Overview + Q&A	Bruce Chapman, NISAR Science Team, JPL/CalTech
10:45 - 11:10	NISAR Utilization Plan	Natasha Stavros, NISAR Deputy Program Applications Lead for Ecosystems, JPL/CalTech
Information Product Requirements		
11:10 - 11:25	NWI	Megan Lang
11:25 - 11:40	USGS: NLCD	George Xian
11:40 - 11:55	BLM	Chris Cole
11:55 - 12:00	Discussion	
12:00 – 1:00	Lunch	

1:00 – 1:15	Ducks Unlimited	Robb McCloud
1:15 - 1:30	NOAA: C-CAP	Nate Herold
1:30 - 1:45	USFS	Raha Hakimdavar
1:45 - 2:00	World Resources Institute	Nancy Harris
2:00 - 2:15	Conservation International	Karyn Tabor
2:15 - 2:30	National Park Service	Brandon Lemire
2:30 - 2:45	TNC	Kathy Boomer
2:45 - 3:00	EPA	Rose Kwok or Myra Price
3:00 - 3:15	Private Sector Carbon Accounting	Steve Crooks, Silvestrum Climate Associates
3:15 - 3:30	Discussion	
3:30 – 3:45	Break	
3:45 - 4:15	Technical Response to Information Requirements Discussion	Bruce Chapman and Marc Simard, NISAR Science Team, JPL, California
4:15 - 4:30	R&D Needs to Address Identified Technical Gaps	Gerald Bawden (NASA/HQ)

DAY 2: Wednesday, October 24, 2018

7:30 - 8	*Arrival & Sign-In*	
Examples of how SAR could be integrated into existing Decision Support Workflows		
8:00 – 8:20	Wetland Classification	Prasad Thenkabail, USGS
8:20 - 8:40	Inundation Maps	Ben Devries and Chengquan Huang, University of Maryland
8:40 – 9:00	Carbon Accumulation in Peatlands	Hinsby Cadillo-Quiroz, Arizona State University

9:00 – 9:20	NASA Applied Science Program Overview	Woody Turner, Ecological Forecasting Applied Science Program Manager (NASA/HQ)
9:20 - 9:30	Discussion	
9:30 – 9:45	Break	
9:45 - 10:05	Coastal Processes	Elijah Ramsey, USGS
10:05 - 10:25	Invasive Species & Vernal Pools	Laura Bourgeau-Chavez, Michigan Tech
10:25 – 10:45	Mangrove Mapping	Nathan Thomas, UMD/GSFC
10:45 - 11:05	Coherence for Wetland Mapping	Brian Brisco, Natural Resources Canada
11:05 - 11:25	Hurricane Response	Bruce Chapman, JPL/CalTech, NISAR ST
11:25-11:45	Water Quality and Watershed Integrity	Laurie Alexander or Jay Christensen, EPA
11:45 - 12	Discussion	
12 – 1	Lunch	
Identifying priority applications and a roadmap before launch		
1 – 3	Detailed Sector requirements (Bruce Chapman and Marc Simard, facilitate group discussion): ● [products] Which wetlands applications products serve multiple agencies/organizations? What are the specifications (data formats, projections, etc) for the NISAR products? ● [roadmap] What is the best way to get from NISAR Level 2 radar products to Wetlands science/application-ready products (Level 3+)? Key data producers/providers? Software tools (GEE, ArcGIS plug-ins, etc.)? What is the best way to distribute/disseminate products? Working Group? ● [training] What kind of capacity building (trainings, etc.) do you need for this community? Who are the key players building capacity in the community? Are there difficulties to using radar; if so, what are they? How do we frame the training to remediate those difficulties?	
3 - 3:15	Break	

3:15 – 4	Work Plan: Steps needed before now and Launch	Natasha Stavros, facilitate Group Discussion
4 – 4:30	Next Steps and Wrap-Up	Gerald Bawden (NASA/HQ/Earth Science)

DAY 3: Thursday, October 25, 2018

7:30 - 8	Arrival & Sign-in
8 - 10:15	Discussion of UAVSAR campaign and Wetlands Working Group at Patuxent (Facilitated by Natasha Stavros)
10:15-10:30	Break
10:30-11:30	Carpool to Jug Bay
11-30-2:30	Jug Bay Field Trip (lecture and tour)

9.2 Participants

First Name	Last Name	Affiliation
Hinsby	Cadillo-Quiroz	Arizona State University
Jodi	Brandt	Boise State University
Christopher	Cole	Bureau of Land Management
David	Hunt	Conservation International
Karyn	Tabor	Conservation International
Robb	Macleod	Ducks Unlimited
Michael	Merchant	Ducks Unlimited
Lori	White	Environment and Climate Change Canada
Laurie	Alexander	Environmental Protection Agency
Jay	Christensen	Environmental Protection Agency
Rose	Kwok	Environmental Protection Agency
Myra	Price	Environmental Protection Agency
Michael	Higgins	Fish and Wildlife Service
Brian	Huberty	Fish and Wildlife Service
Megan	Lang	Fish and Wildlife Service
Chapman	Bruce	Jet Propulsion Laboratory, California Institute of Technology
Cathleen	Jones	Jet Propulsion Laboratory, California Institute of Technology
Marc	Simard	Jet Propulsion Laboratory, California Institute of Technology
Natasha	Stavros	Jet Propulsion Laboratory, California Institute of Technology
Laura	Bourgeau-Chavez	Michigan Technology Research Institute
Nathan	Thomas	NASA
Batu	Osmanoglu	NASA Goddard
Michael	Falkowski	NASA HQ
Bawden	Gerald	NASA HQ
Woody	Turner	NASA HQ
Clay	Blankenship	NASA Marshall
Nate	Herold	National Oceanic and Atmospheric Administration
Frank	Monaldo	National Oceanic and Atmospheric Administration
Brandon	Lemire	National Park Service
Greg	Pipkin	Natural Resource Conservation Service
Brian	Brisco	Natural Resources Canada Canada Centre for Mapping and Earth Observations
Stephen	Crooks	Silvestrum Climate Associates
Kathy	Boomer	The Nature Conservancy
Ben	DeVries	University of Maryland
Chengquan	Huang	University of Maryland

Raha	Hakimdavar	US Forest Service
John	Jones	US Geological Survey
Elijah	Ramsey III	US Geological Survey
Jennifer	Rover	US Geological Survey
Gregory	Snyder	US Geological Survey
Prasad	Thenkabail	US Geological Survey
George	Xian	US Geological Survey
Nancy	Harris	World Resources Institute

9.3 Acronyms

Acronym	Description
ACEP	Agricultural Conservation Easement Program
AIM	Assessment, Inventory, and Monitoring
ALE	Agricultural Land Easements
BLM	Bureau of Land Management
BW	pulse bandwidth
CI	Conservation International
COV	Polarimetric Covariance Matrix
CP	Compact Polarimetry
DEM	Digital Elevation Model
DOI	Department of Interior
DP	dual-polarization
DSWE	Dynamic Surface Water Extent
EPA	Environmental Protection Agency
EROS	Earth Resources Observation and Science
FGDC	Federal Geographic Data Committee
FWS	Fish and Wildlife Service
GCOV	Geocoded Polarimetric Covariance Matrix
GIFG	Geocoded Nearest-Time Interferogram
GFED	Global Fire Emissions Database
GFW	Global Forest Watch
GIS	Geographic Information System
GLAD	Global Land Analysis and Discover
GSLC	Geocoded SLC
GTAC	Geospatial Technology Applications Center
GUI	Graphical User Interface
GUNW	Geocoded Nearest-Time Unwrapped Interferogram
IDIQ	Indefinite Delivery/Indefinite Quantity
InSAR	Interferometric SAR
ISRO	Indian Space Research Organisation
L#	Data Product Level #
NASA	National Aeronautics and Space Administration
NCEA	National Center for Environmental Assessment
NERL	National Exposure Research Laboratory
NGDA	National Geospatial Data Asset
NHEERL	National Health and Environmental Effects Research laboratory
NIR	Near Infrared

NISAR	NASA-ISRO Synthetic Aperture Radar
NITF	National Imagery Transmission Format
NLCD	National Land Cover Database
NLI	National Land Imaging
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Services
NPS	National Park Service
NRCS	National Resource Conservation Services
NRT	Near-Real Time
NWCA	National Wetland Condition Assessment
NWI	National Wetland Inventory
OCM	Office for Coastal Management
PolSAR	polarimetric SAR
QD	co-polarization
QP	quad-polarization
QQ	Quasi-quad polarization
R	right circular polarization
SAR	Synthetic Aperture Radar
SFFAS	Statements of Federal Financial Accounting Standards
SLC	Single Look Complex
SP	single-polarization
SSURGO	Soil Survey Geographic Data Base
TNC	The Nature Conservancy
UAS	Unmanned Aerial Systems
UAVSAR	Uninhabited Aerial Vehicle Synthetic Aperture Radar
USFS	US Forest Service
USGS	US Geological Survey
UTM	Universal Transverse Mercator
WFWARP	Watershed, Fish, Wildlife, Air, and Rare Plants
WHRC	Woods Hole Research Center
WPA	Waterfowl Production Areas
WRE	Wetlands Reserve Easements
WRI	World Resources Institute